IEEE802.21 OPTIMIZED HANDOVER DELAY FOR PROXY MOBILE IPV6

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ABSTRACT

Next generation wireless networks are envisaged to be a combination of different but complementary access technologies. Interworking of these heterogeneous wireless networks will provide ubiquitous access to roaming network users. Thus, a seamless mobility mechanism with low handover delay to maintain active communication flows during handover across these networks is required. Several solutions, mainly host-based localized mobility management schemes, have been widely proposed to reduce handover delay in heterogeneous wireless networks. However, the handover delay remains high and unacceptable for delay-sensitive services. Moreover, host-based mobility management schemes involve the mobile node in mobility-related signaling hence effectively increasing the handover delay. This paper analyzes the reduction of handover delay in a network-based localized mobility management framework assisted by IEEE 802.21 Media Independent Handover services. It compares the handover signaling procedures with host-based localized Mobile IPv6 (HMIPv6), with network-based Mobile IPv6 (PMIPv6), and with PMIPv6 assisted by IEEE 802.21 to show how much handover delay reduction can be achieved.

I. INTRODUCTION

Next generation wireless networks (NGWN) will have an all-IP based infrastructure with the support of heterogeneous access technologies [1]. Thus, mobile users with multimode mobile devices will be able to roam across these IP-based heterogeneous wireless networks with uninterrupted active connections. However, mobility management across these wireless heterogeneous networks is still a challenge. Advanced mechanisms are required to ensure that seamless service continuity, particularly for real-time applications, is sustained as a mobile device switches from one wireless access network technology to another. More so, NGWN will provide real-time and multimedia applications [1] which are inherently intolerant of handover delays.

The early widely proposed handover delay reduction techniques are based on host-based mobility management schemes [2]. In particular, Mobile IPv6 (MIPv6) [3] extensions, Hierarchical MIPv6 (HMIPv6) [4] and Fast Handover for MIPv6 (FMIPv6) [5], have been proposed as experimental protocols by IETF to reduce handover delay. HMIPv6 localizes handover registration while FMIPv6 performs address pre-configuration in an effort to reduce handover delay. When used on its own in an end-to-end approach, the basic MIPv6 suffers large handover latencies due to end-to-end signaling [6]

In fact, it has been discovered that the management of mobility can be more efficiently handled if it is divided into global mobility management and localized mobility management [7]. Thus, HMIPv6 and FMIPv6 are utilized to optimize MIPv6's performance in terms of reducing the handover delay and hence service degradation during the handover process. HMIPv6 is a host-based mobility management scheme suitable for localized domains while MIPv6 is best suited for global mobility management. Other localized-mobility management protocols such as Cellular IP, IDMP and HAWAII have also been proposed by other standards bodies. The main goal of localized mobility management protocols is to reduce handover delay (by localizing registration hence reducing end-to-end delay) so that seamless service continuity can be achieved during roaming. Handover delay is mainly due to delays caused by discovery, configuration, authentication, and binding update procedures associated with a mobility event [8]. For handover with seamless service continuity particularly for real-time applications, handover delay has to be reduced.

Low or negligible handover delay is a requirement for delay-sensitive applications, for example, military applications which demand timely and higher performance. Reduced handover delay would, for example, enhance the maintaining of seamless communications as military vehicles move about in a terrain where network topology changes continuously and unpredictably. In fact, for both commercial and military networks, it is increasingly important to be able to locate and maintain ongoing sessions with a mobile user or node [9].

Many proposed mobility management schemes are host-based, that is, the MN is directly involved in mobility-related signaling. However, to accommodate mobility-related signaling, the conventional signaling messages are

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extended, hence resulting in heavier messages. These extended messages take longer to process and to cover the round-trip-time distance since they have to first traverse the unpredictable air link between the MN and the default access router of the network, hence effectively increasing the handover delay. Thus, there are still some challenges pertaining to reducing handover delay with the widely proposed host-based localized-mobility management schemes.

This paper, therefore, analyzes the reduction in handover delay in the recently emerged IETF network-based localized mobility management scheme, Proxy Mobile IPv6 [10], in place of the earlier widely proposed host-based localized mobility management schemes. Proxy Mobile IPv6 (PMIPv6), by its specification, reduces the mobility related signaling round-trip-time delay, hence the handover latency, by excluding the MN from mobility-related signaling. However, in network-based mobility management schemes, network access authentication contributes significantly to handover delay [6]. Thus, an IEEE 802.21-assisted PMIPv6 may reduce the authentication delay, and hence effectively further reducing the handover delay. An analytical performance evaluation comparison in terms of the handover delay in standard PMIPv6, HMIPv6 and the IEEE 802.21-enabled PMIPv6 domain is presented and it is observed that the latter scheme performs better. The analysis focuses on an IEEE 802.21-enabled MN that roams between subnets within an IEEE 802.21-enabled PMIPv6 domain.

The rest of the paper is organized as follows: Section II reviews some related work on reducing handover delay. Section III briefly discusses the operational and functional architecture of PMIPv6. Section IV summarizes the qualitative impact of the IEEE 802.21: Media Independent Handover (MIH) services. Section V presents the analytical comparison of handover delay performance in PMIPv6, HMIPv6, and the IEEE 802.21-assisted PMIPv6 scheme. Section VI concludes the paper.

II. RELATED WORK

One of the challenges in NGWN mobility management is reducing handover delay [11] to prevent perceptible disruption of active real-time applications during handover among heterogeneous wireless networks. Since handover delay comprises different delay causing components, researchers have proposed different ways of reducing handover delay. [12] proposes to reduce handover delay by using a proactive correspondent registration mechanism for PMIPv6 route optimization between the correspondent node (CN) and mobile access gateway (MAG). However, route optimization inherently introduces more signaling messages between the MAG (on behalf of the MN) and the CN. In [13] a fast handover scheme for PMIPv6 is proposed to reduce handover delay. It applies Inter-Access Point Protocol to transfer context information in advance to a new mobile access gateway. However, this scheme is only applicable to 802.11 networks.

Whereas network-based localized mobility management has recently emerged, most works have proposed host-based localized mobility management schemes to reduce handover delay. In [14] the handover procedure in FMIPv6 is optimized by using IEEE 802.21 MIH services. In particular, the delay due to radio access discovery and candidate access router discovery is tackled. In [15] a framework that is based on Fast Handover for Hierarchical Mobile IPv6 and Optimistic Duplicate Address Detection to reduce handover delay is proposed. Notably though, most of the host-based mobility management schemes avoid addressing the issue of authentication delay yet it contributes significantly towards handover delay.

III. PROXY MOBILE IPV6 (PMIPV6)

PMIPv6 is a network-based localized mobility management scheme that enables IP mobility for an MN without requiring its participation in any mobility-related signaling. The network is responsible for managing IP mobility on behalf of the MN. A typical PMIPv6 domain is shown in Fig. 1.

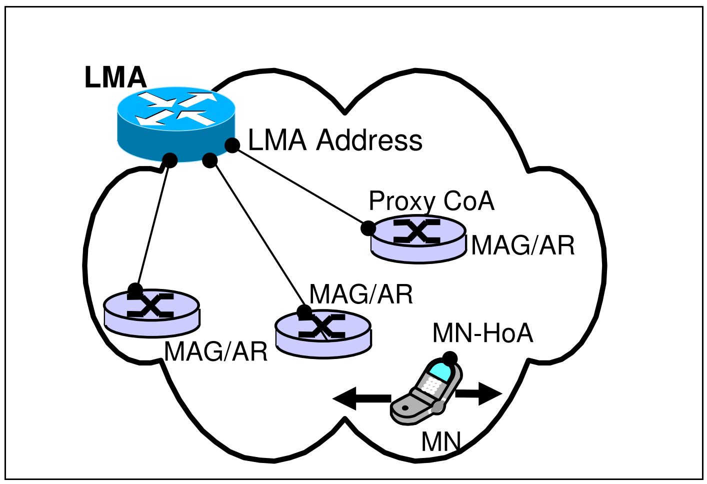

Figure 1. Proxy Mobile IPv6 domain.

The PMIPv6 domain introduces two new network functional entities called Local Mobility Anchor (LMA) and Mobile Access Gateway (MAG). The LMA is the local home agent (HA) of the MN in the PMIPv6 domain and further provides additional capabilities required for network-based mobility management. It is equivalent to the mobility anchor point (MAP) in a HMIPv6 domain since it is also the topological anchor point for the MN's home network prefix and is the entity that manages the MN's binding state [10]. The MAG, on the other hand, is a functional entity that handles all mobility-related signaling on behalf of an MN attached to its access links. It is typically implemented in the default access router (AR). It tracks the movement of the MN, authenticates it (MN) and initiates the required mobility signaling on behalf of the MN. The communication between the MAG and the LMA is via an established bidirectional tunnel between them. The tunnel or transport endpoints are the LMA address and Proxy Care-of-address as seen in figure 1. Communication with the MN is through the MN's home address (MN-HoA).

In a nutshell, PMIPv6 operation in terms of handover consists of: attachment and authentication, binding update and binding acknowledgment, IP address configuration, and duplicate address detection (DAD). IP address configuration and DAD are mainly relevant only when the MN first enters the PMIPv6 domain. The PMIPv6 protocol ensures that the MN maintains the same home address configuration as long as it is in the domain. That is because the PMIPv6 specification supports Per-MN-Prefix model [10] where a unique home network prefix is assigned to each MN and no other node shares an address from that prefix in the domain.

The air link interface between the MN and the AR (which implements the MAG functionality) has no mobility related signaling overhead. Thus, the mobility-related signaling round-trip-time is reduced, hence ultimately reducing the handover delay as compared to a host-based localized mobility management scheme. However, network based localized mobility management schemes suffer from significant access network authentication delay [6].

IV. MEDIA INDEPENDENT HANDOVER SERVICES

The IEEE 802.21 working group has created a framework that defines a Media Independent Handover Function (MIHF) which assists with seamless handover across heterogeneous link-layer technologies thus providing better performance to users during mobility events across heterogeneous networks. Basically, IEEE 802.21 (Media Independent Handover Services) [16] technology defines information exchanges that provide topological and location related information of service networks, timely communications of wireless environment information, and commands that can change the state of the wireless link. The MIHF is logically located between layer 2 and layer 3 in the protocol stack of both the MN and network. Thus, it supports the cooperative use of both MN and network infrastructure in making handovers. MIHF provides services to the upper layers through a unified interface, the Service Access Point (SAP), which hides the heterogeneity of the access technologies. The lower layer protocols communicate with the MIHF through media dependent SAPs.

The MIHF has three functional components that are designed to provide services to assist with seamless handover across the heterogeneous networks:

1) Media Independent Event Service (MIES) offers services to upper layers by reporting dynamically changing lower layer events. These events are reported only to upper layer mobility protocols (MIH users) that have registered to receive a particular set of events and hence get alerted as those events happen. Some commonly defined events include *link up, link down, etc*. which are based on reports on throughput, packet loss, etc of the lower layers. The MIH users would then act based on receiving these notifications to determine whether to handover or not and a target optimal network to handover to.

2) Media Independent Information Service (MIIS) basically provides static information about characteristics and services of the serving and neighboring networks to both higher and lower layers. The information provided includes network type, link information, security information, service level agreements, cost, etc. The information is made available via both lower and upper layers through a query/response mechanism. To ensure transparency of the access technologies, this information is represented by the use of standard formats. With the necessary information, an MN may discover available neighboring networks and communicate with elements within these networks a priori to optimize handover.

3) Media Independent Command Service (MICS) is provided to the upper layers to enable them to control and manage the functions of the lower layers. The MICS commands are used to execute higher layer mobility and connectivity decisions to the lower layers. Example MICS commands are *poll, scan, configure, handover commit, etc*.

So, basically IEEE 802.21 performs a report mechanism that conveys useful mobility-related information to entities where a decision is made to cause a command to be executed at some specific network elements to facilitate seamless handover. Hence, the handover process is facilitated by the information provided from the network to the MN, in addition to the information that the MN collects from the lower layers. This cooperative information exchange enhances handover optimization.

V. ANALYTICAL COMPARISON OF HANDOVER DELAY PERFORMANCE

A. Proxy Mobile IPv6

The basic signaling call flow diagram of handover in a PMIPv6 domain is shown in Fig. 2. Notably, the binding registration messages are initiated from the MAG, which is in the network infrastructure, as opposed to host-based mobility management schemes such as HMIPv6 (as will be seen later) where the same signaling is initiated from the MN.

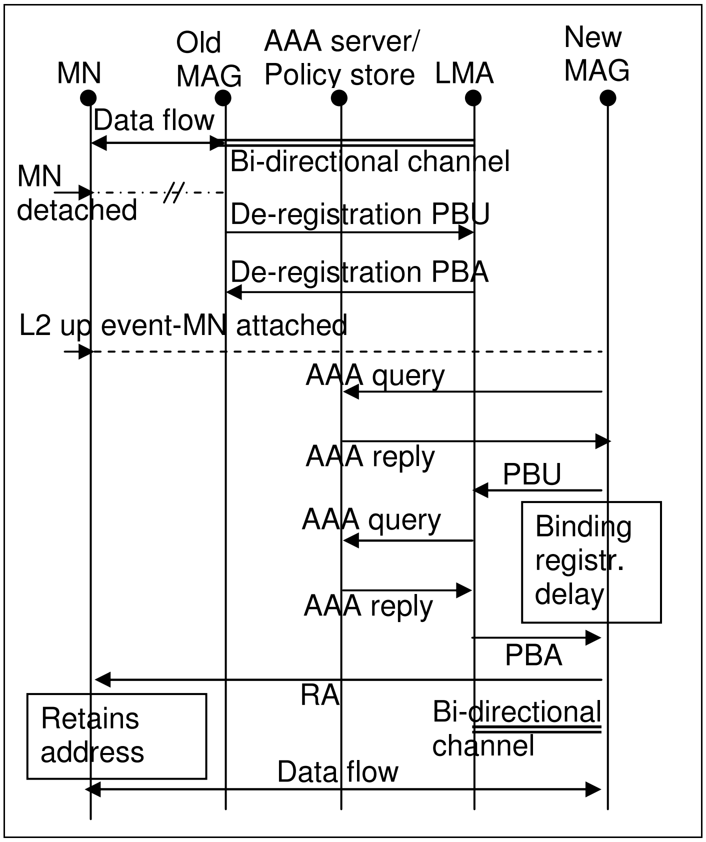

Figure 2. Signaling Call Flow of MN handover in PMIPv6 domain.

For clarity, the round-trip signaling call flow diagram showing the handover latency during MN handover to a new MAG in a basic PMIPv6 domain is shown in Fig. 3. Evidently, the handover delay in PMIPv6 is due to many processes that take place during handover; the attachment notification delay due to the event that informs the MAG of an MN's attachment D_{ATTACH}, the authentication delay (query(Q) and reply(R) messages) due to the MAG verifying if the attaching MN is eligible for network-based mobility management service $D_{AUTH} = D_Q + D_R$, another authentication delay where the LMA verifies the authenticity of the MAG sending the proxy binding update $D_{AUTH\_2} = D_{Q2} + D_{R2}$, the proxy binding registration delay $D_{BINDING} = D_{PBU} + D_{PBA}$ where the MAG performs mobility-related signaling on behalf of the MN, the router advertisement delay D_{RA} where the MAG advertises the necessary information, some of which is obtained from the LMA, for the MN to configure its address in the domain and to know its default access router, the actual IP configuration delay D_{CONF}, and the duplicate address detection delay D_{DAD}. DAD is for checking if the local address configured by the MN is not already configured by another MN in the same MAG link. In fact, D_{CONF} and D_{DAD} are not appreciable when the MN is already roaming in the PMIPv6 domain.

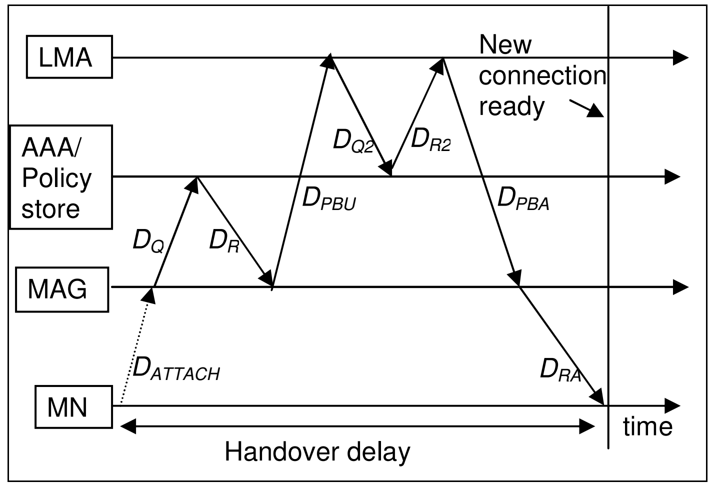

Figure 3. PMIPv6 signaling call flow showing handover delay.

Delays are inevitable during vertical handover although they can be optimized or reduced (or made transparent to the active connections). The various delays during the handover process between MAGs in the PMIPv6 domain contribute differently to the overall handover latency. Hence, active real time communication which an MN might be having with a CN may be interrupted due to the handover latency which normally results in packet losses.

It should be appreciated that the handover delay is lower in PMIPv6 when compared to that in a host-based localized mobility management schemes by virtue of having the MN not getting involved in mobility-related signaling. That is, the binding update delay is shorter in PMIPv6 since it is carried out by a MAG (which is in the network infrastructure) instead of the MN which is usually further away from the LMA than the MAG is in a PMIPv6 domain. In this paper, we assume that only the user device (MN) is mobile while the rest of the network infrastructure is not. Furthermore, we assume a 2-level hierarchical structure in the PMIPv6 domain.

Also, since in a PMIPv6 domain the MN keeps its address as long as it is inside the domain, the IP configuration and DAD process delays are negligible, unlike in host-based mobility management where these processes are performed completely anew every time an MN changes its PoA in the domain.

Thus, overall handover delay in basic PMIPv6 is the sum of the individual delay components:

$$D_{PMIPv6} = D_{ATTACH} + D_{AUTH} + D_{AUTH\_2} + D_{BINDING} + D_{RA}. \quad (1)$$

We assume that $D_{ATTACH} \neq D_{RA}$ since the router advertisement (RA) and MN attachment signals carry different messages hence are bound to encounter different delays.

Also, according to [10] the MAG can learn the MN's link-local address by snooping DAD messages sent by the MN for establishing the link-local address uniqueness on the access link. Subsequently the MAG can obtain this address from the LMA at each handover to ensure link-local address uniqueness (LMA is assumed to have the overall knowledge of the PMIPv6 domain) and change its own link-local address if it detects a collision. Thus D_{DAD} is not appreciable.

B. Hierarchical MIPv6 (HMIPv6)

Fig. 4 shows a basic signaling call flow diagram for a host-based localized mobility management scheme, HMIPv6.

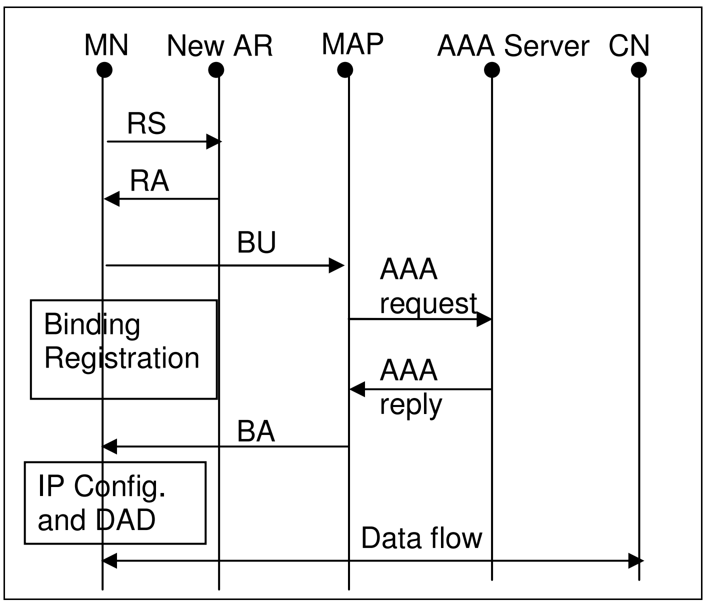

Figure 4. HMIPv6 domain handover signaling call flow.

It is evident from this figure that the MN is directly involved in mobility-related signaling. Therefore, the binding registration (BU and BA) time is longer in a host-based localized mobility management scheme than in a network-based localized mobility management scheme. We are assuming that both the PMIPv6 and HMIPv6 domains have 2-level hierarchical structures, and only the MNs are mobile. Thus, $D_{BINDING(HMIPv6)} > D_{BINDING}$, where $D_{BINDING(HMIPv6)} = D_{BU} + D_{BA}$. Also, movement detection delay $D_{MD} = D_{RS} + D_{RA}$ and D_{DAD} are known to be long and time-consuming operations that can degrade handover performance significantly in host-based mobility management schemes as mentioned in [17]. Therefore, $D_{MD} > D_{ATTACH}$ where $D_{ATTACH} \approx D_{RS}$ ($\neq D_{RA}$). The handover delay in HMIPv6 is,

$$D_{HMIPv6} = D_{MD} + D_{BINDING(HMIPv6)} + D_{AUTH} + D_{CONFIG} + D_{DAD}. \quad (2a)$$

Hence, in terms of PMIPv6 delay notation, $D_{BINDING(HMIPv6)} \approx D_{PBU} + D_{PBA} + D_{ATTACH} + D_{RA}$ and $D_{MD} \approx D_{ATTACH} + D_{RA}$. Of note is that according to [10] the MAG in PMIPv6 only sends the router advertisement (RA) after completing the binding registration with the LMA, unlike in HMIPv6 where RA is sent to MN before binding registration. The handover delay in HMIPv6 in terms of PMIPv6 delay notation is,

$$D_{HMIPv6} = 2D_{ATTACH} + 2D_{RA} + D_{BINDING} + D_{AUTH} + D_{CONFIG} + D_{DAD}. \quad (2b)$$

Furthermore, a HMIPv6 mobility stack is added in the MN's protocol stack as opposed to the PMIPv6 scenario where the addition of a mobility stack is not necessary as long as the MN roams within the domain. This adds complexity to the MN.

C. IEEE 802.21-assisted PMIPv6 scheme

With IEEE 802.21 MIH services, the MN and the PMIPv6 domain network entities, in particular the MAG or access router (AR), are informed about parameters necessary in handover decision prior to the actual handover process. Furthermore, intelligent handover decisions to optimal subnets are made with collaboration between the MN and the network entities. Thus, the MIH services enhance network discovery and selection. The IEEE 802.21-assisted PMIPv6 scheme exploits the services of the MIHF to reduce handover delay, in particular, the access authentication delay component which can cause significant delay in network-based mobility management handovers.

MIH services enable some operations to be performed prior to the handover process while the MN is still connected to the old MAG link. Thus, when the handover is eventually performed, there will be fewer delay-causing phases executed. For example, the authentication delay is dealt with by enabling the new MAG to authenticate the MN ahead of time.

Utilizing the MIIS service, the MN and AR/MAG get to know of their heterogeneous neighboring networks' characteristics by requesting from information elements at a centralized information or MIIS server (which comprises a policy store and AAA server). The information server is assumed to be collocated with the LMA in this paper as shown in Fig. 5.

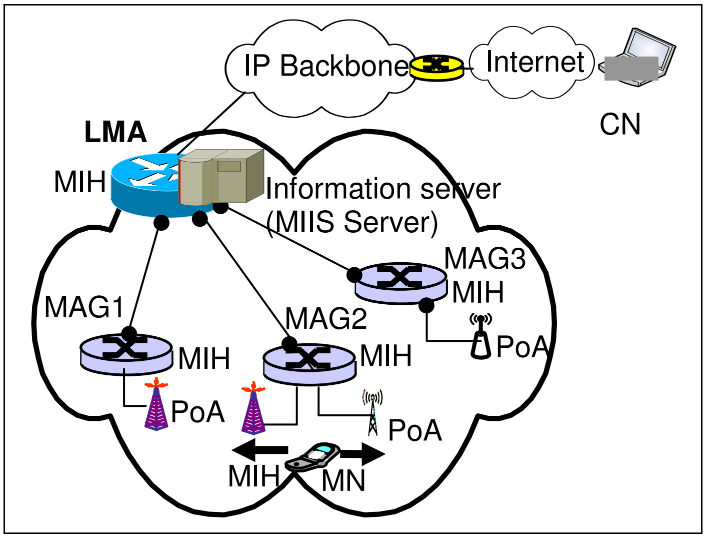

Figure 5. IEEE 802.21-enabled PMIPv6 domain and Mobile Node.

The information elements in the server provide information that is essential for making intelligent handover decisions, such as, general information and access network specific information (e.g. network cost, security, QoS capabilities, service level agreements, etc.), point of attachment specific information (e.g. proxy care-of-address, data rates, MAC addresses, etc.), and other access network specific information.

Dynamic information such as attached MNs' policy profiles together with authentication information (with relevant cookies) and stable identities of the MNs is also included in the information server. Consequently, every MAG is always aware of its neighboring environment by utilizing MIH services to get information by requesting from the information elements in the central information server.

The MIH services, i.e. MIES and MICS, are triggered by different dynamic events such as the attachment or detachment events of a MN in a MAG and varying handover decision parameters exceeding predefined thresholds. In particular, the MIES service notifies relevant handover decision engines about imminent handover while also updating the information server. Maintenance of the information server is very feasible since the localized PMIPv6 domain is possibly administered by a single operator or by cooperating service providers.

Assuming a trust relationship between the MAGs in the IEEE 802.21-enabled PMIPv6 domain, and through the utilization of proactive signaling deliberations via MIH services between the MAGs (on behalf of the attached MNs) and the Information server, a new MAG will immediately get information about MNs attaching to neighboring MAGs including authentication information. For example, when an MN is handed over from an old MAG (e.g. MAG1) to a new MAG (e.g. MAG2), then MAG2 would already be having information about the MN ahead of time through the MIIS server. On obtaining the information from the server (through MIH services), MAG2 authenticates the MN based on handover policies in anticipation of a handover towards itself (MAG2) in the near future. Thus, technically the MN is attached (hence, $D_{ATTACH} \rightarrow 0$) to MAG2 if its service requirements pass some call admission control procedures. However, no resources are reserved until the actual handover happens and the MN has literally attached to MAG2's link. The assumption is that the old MAG (MAG1) has already authenticated the MN and sent the MN's authentication information (with relevant cookies) and policy profile to the server through MIH services since it (MN) is already in the PMIPv6 domain and receiving as well as sending information to correspondent nodes (CNs) before the handover.

Ultimately, the authentication procedure, as well as the attachment notification phase is eliminated from the actual handover process hence reducing handover delay. In that way, the handover process will not be impeded by authentication delay. However, the early authentication process comes with the expense of reduced security. To increase the security provision, the authentication procedure will have to be performed normally once the handover completes and the MN has literally attached to the new MAG. To save resources, once a MN leaves the domain or becomes inactive for a certain predefined period, all its information is deleted from the information server.

Thus, the handover delay due to our proposed scheme is significantly reduced and is,

$$D_{PMIPv6(802.21)} = D_{BINDING} + D_{RA} \quad (3)$$

A typical signaling call flow for the IEEE 802.21-assisted PMIPv6 is as shown in Fig. 6. However, for clarity, the details of the involved specific MIH information messages and handover message primitives are not shown in the figure. Instead, they are collectively depicted as MIH information updates and MIH handover messages.

Thus, the considerably reduced handover delay will ensure real-time service continuity for delay sensitive services, for example, for military communication where there is high mobility in dynamic or heterogeneous wireless networks.

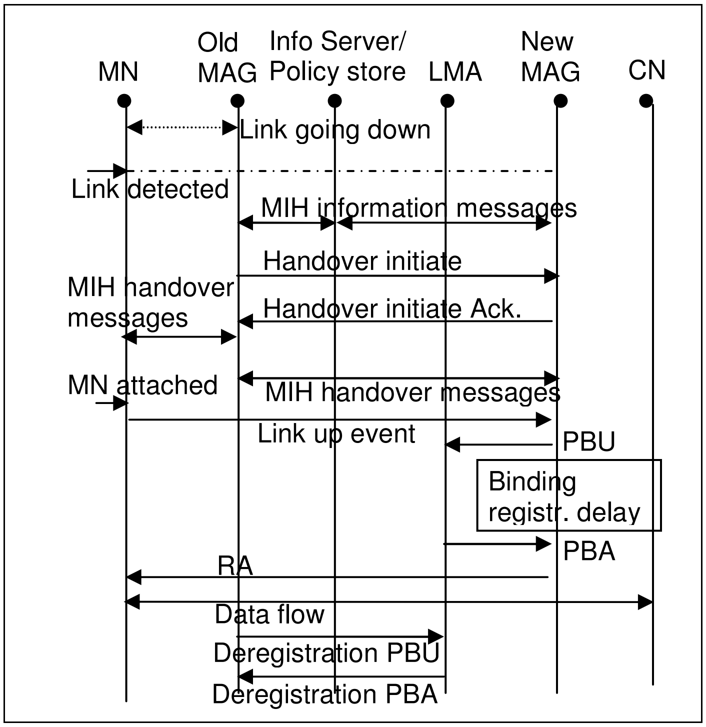

Figure 6. Signaling call flow for IEEE 802.21 assisted PMIPv6 handover process.

In utilizing the MIH services, the authentication procedure is performed in the new point of attachment while the MN is still attached to its old MAG hence reducing handover delay which normally disrupts real-time service continuity during the actual handover process. PMIPv6, on the other hand, reduces binding update delay hence ultimately reducing the handover delay.

VI. CONCLUSION

In this paper, we analyze a mechanism which optimizes the PMIPv6 handover process with the assistance of IEEE 802.21 MIH services. We show through analysis of the signaling procedures that the mechanism performs better that basic PMIPv6 and the host-based HMIPv6 in terms of reducing handover delay. The mechanism performs proactive signaling deliberations among the PMIPv6 domain elements hence eliminating the authentication delay from the actual handover process. Authentication information, policy profiles, and stable identities of attached MNs are included in the MIIS server to enhance the handover performance. Thus, neighboring MAGs have information about each other as well as attached MNs hence helping PMIPv6 to tackle the issue of access authentication in advance. The mechanism, therefore, reduces handover delay significantly by eliminating the authentication as well as the attachment notification phases from the actual handover process. Furthermore, the utilization of PMIPv6 reduces the round-trip-time hence the binding update delay, and ultimately the handover delay.

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